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A PATTERN FOR WESTERN STEEL PRODUCTION

BY

H. FOSTER BAIN

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

A PATTERN FOR WESTERN STEEL PRODUCTION[1]

By H. Foster Bain[2]

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INTRODUCTION

The war has brought about many changes in the Western States, and some have deep present or potential economic significance. The West has been feeling severe growing pains for a number of years. Especially since the beginning of preparation for national defense and through the period of

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[2] One of the consulting engineers, Bureau of Mines, U. S. Department of the Interior.

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production for war have these been in evidence. There has been a large influx of workers and their families who must be provided with a way to make a living after the war; great hydroelectric power plants have been brought into production, and these hunger for post-war jobs; many new factories have been built and old ones enlarged or rejuvenated, and these are now available for the manufacture of consumer goods. The people of the Western States have become increasingly conscious of the resources and possibilities of the region as regards development. Important decisions have had to be made hurriedly in the wartime, and many new projects have been put into execution. In the confusion of building to win the war it was impracticable also to build for the peace. It is inevitabl that the West will find its industries out of balance. Some of the new plants will necessarily be scrapped and abandoned. Others may wisely be put into stand-by condition and held for a time as insurance against further wars. Still others will fit into the peacetime needs of industry or by alteration may be made to do so.

It would be easy to be too pessimistic as to the amount of war plant that will fill no useful purpose in peacetime. Aside from the works employed in manufacture of actual munitions and specific implements of war, all make things that have a peace use. Some will undoubtedly be found too large for the immediate needs of industry; but consumption has been growing in the West even faster than elsewhere, and in time nearly all of the output of these new factories should find a market. The practical problem is how wide a gap will exist between the capacity to produce and the market demand and how long it will take increases in market to catch up with the post-war capacity. Meanwhile, until war demand slacks off, production at capacity is to be anticipated, which allows a little time at least in which to prepare for the inevitable slump that follows all wars.

Pre-war Expansion of the West

The West was growing long before war demand touched its industries. For years back the population of the 11 Western States (Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Nevada, Utah, California, Oregon and Washington) has been increasing more rapidly than that of the country as a whole. This is shown in the diagram, figure 1.3/

This more rapid growth is an expression of the fact that these States had previously been less well-populated than the older States of the East, South, and Middle West, where settlement, as contrasted with exploration, began earlier. The West is nearer the beginning and so on the steep part of the curve of population increase. This is expressed in figure 2, in which the per capita increase per square mile is plotted. The increasing relative importance of population of the West as compared with the remainder of the country, plotted in figure 3, marks it off as one in which industry is growing at a faster than average rate. More people are coming in, and more people require more goods. The situation also

3/ Figures 1 to 4 were prepared by David M. Polak, senior economist, Economics and Statistics Branch, Bureau of Mines.

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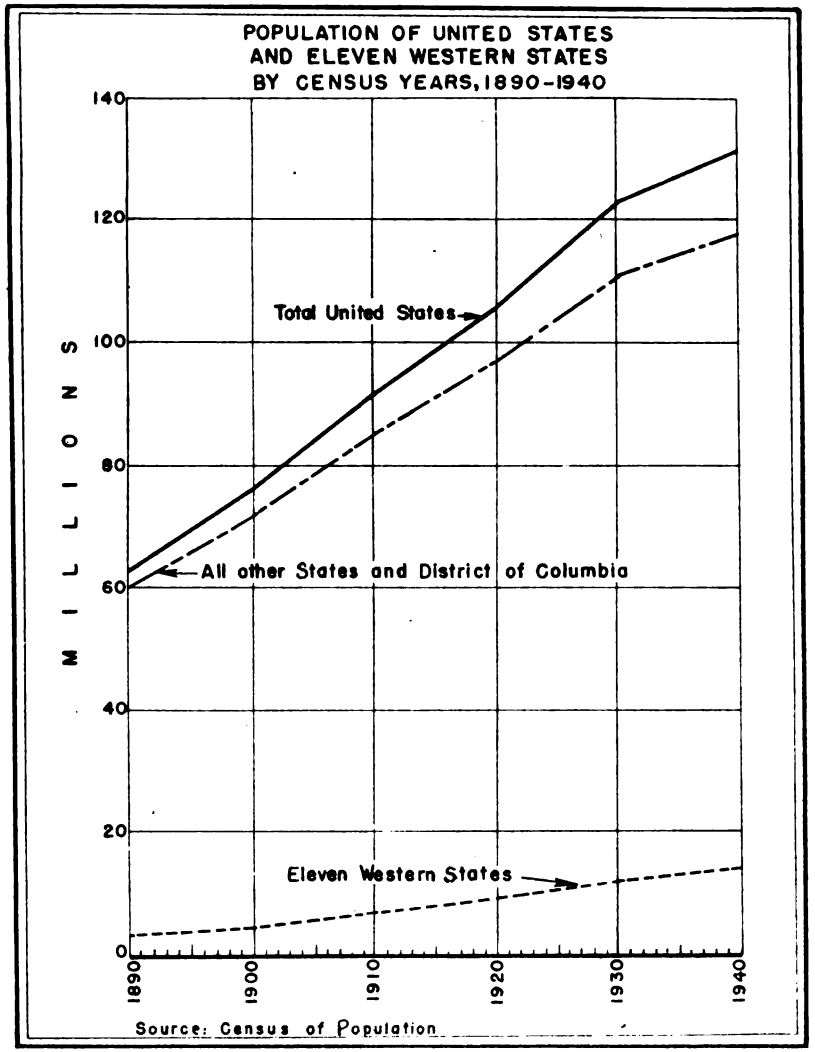

FIGURE 1.- Greater increase in population in Western States than in the United States as a whole.

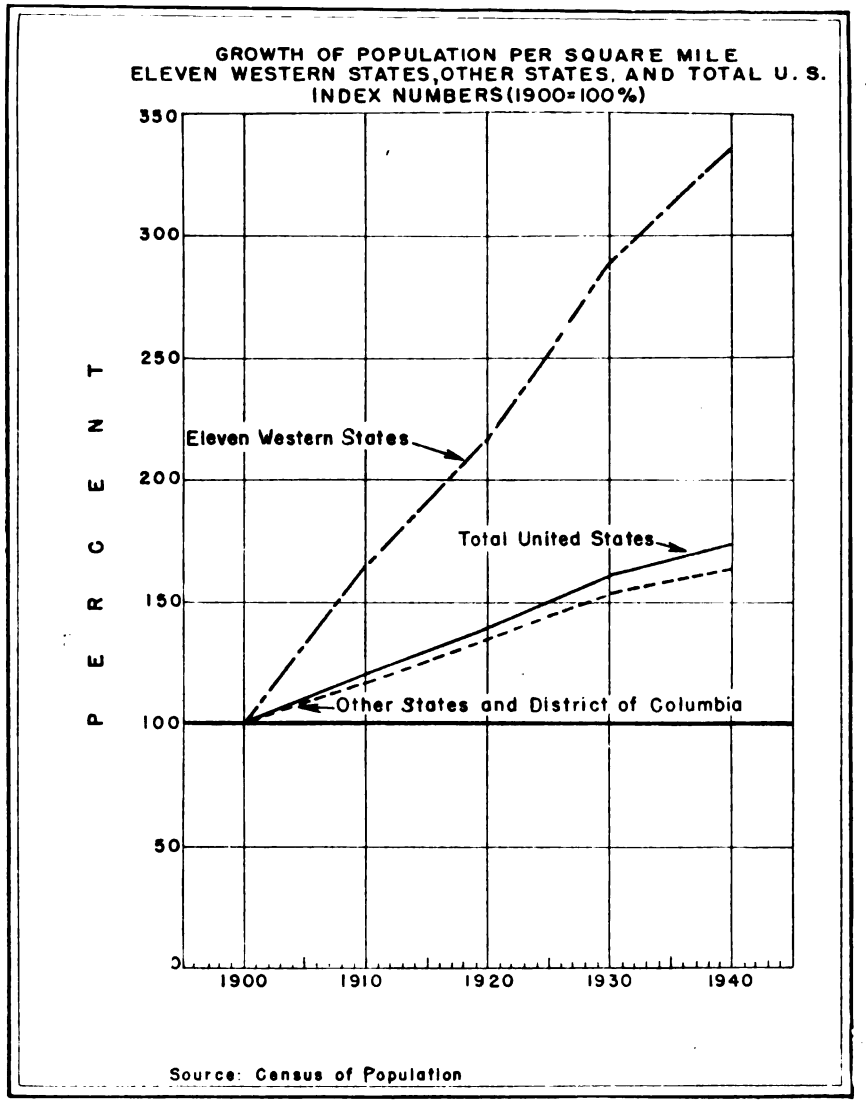

FIGURE 2.- Greater increase in density of population in Western States than in the United States as a whole in the present century.

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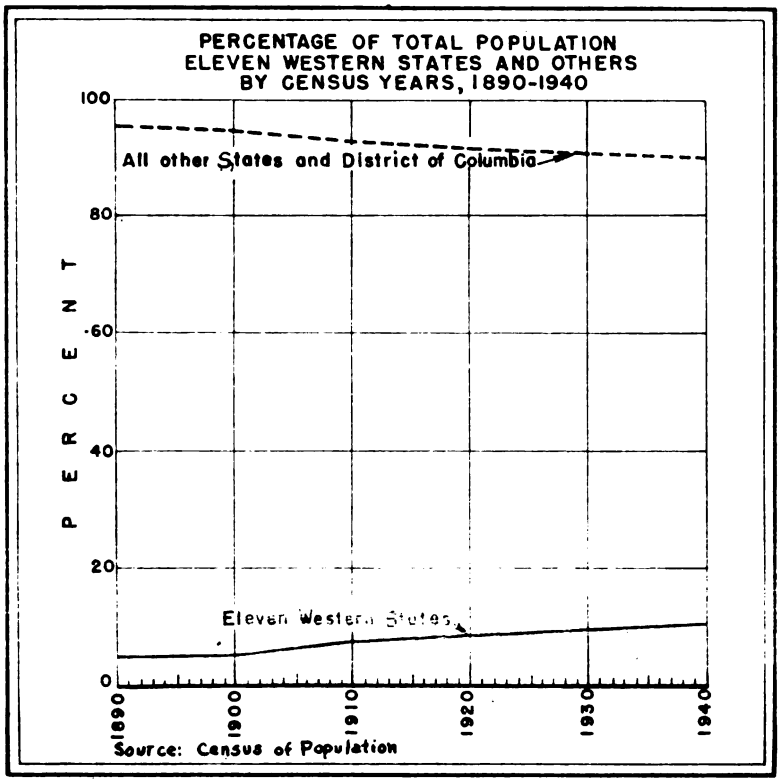

FIGURE 3.- Increase in percentage of population in Western States in the past half century.

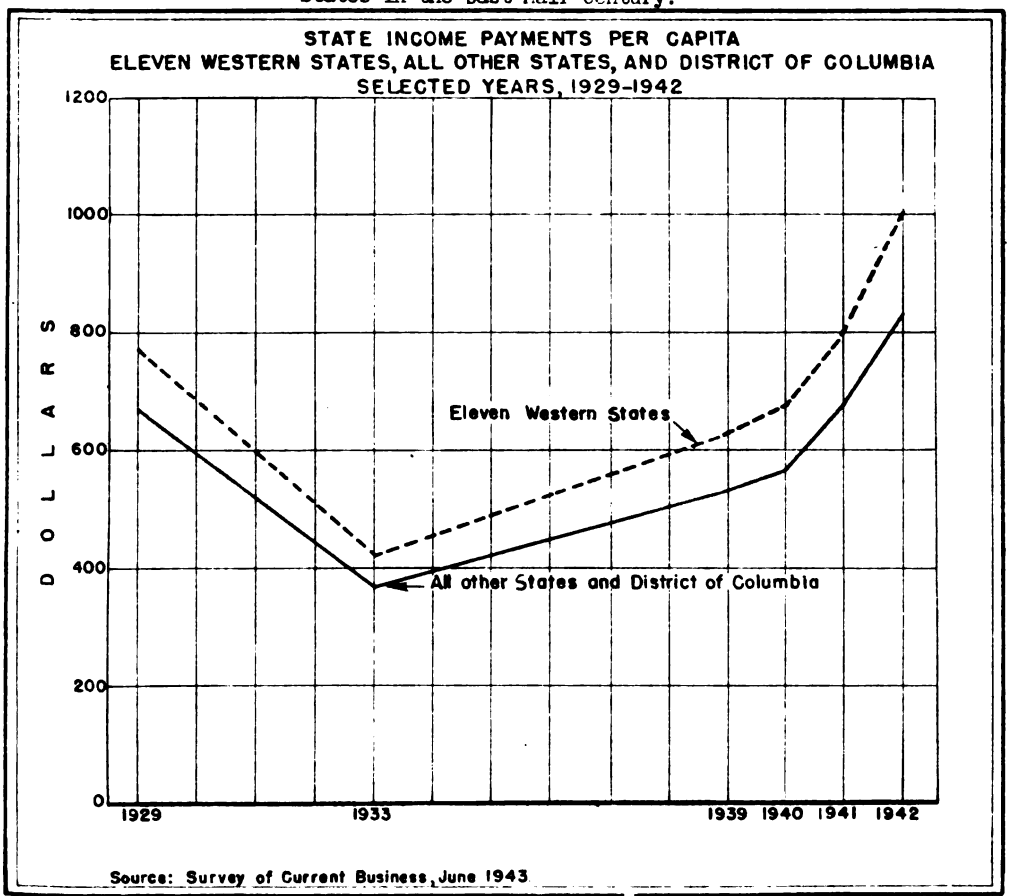

FIGURE 4.- More rapid increase in per capita income payments in Western States.

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favors industrialization, since by no means all of the newcomers wish to go into agriculture. Even now the West produces more agricultural products than it consumes and so is an exporter of these at the same time that it is an importer of manufactures. With a steady and marked increase in the number of local consumers, it is inevitable that a growth in manufacture and industry will follow so far as raw materials may be available and as the local market becomes large enough to absorb the output of plants each of sufficient size to be efficient in manufacture and competitive as to sales. This, of course, assumes that the local standard of living will be kept high enough to keep up the demand and that the local wages and wealth will be sufficient to give the necessary purchasing power. One needs only to visit the West to realize that it is a region in which the standard of living is high, and there is evidence that the per capita purchasing power is considerably above the average for the United States, as indicated in figure 4.

It will not do to rely only on increasing population and high purchasing power. Not everything can be efficiently made in every place, and industries show a notable disinclination to scatter out into untried fields from an area in which they have long flourished. Because of this, importing rather than local manufacture very generally marks the beginnings in any country or region. The manufacturer who supplies the imports naturally tries his best to hold his market. If necessary, he will for some time absorb freight charges to hold or gain such a market. This conservative attitude is not due merely to stubbornness on the part of owners or management; it applies to workers as well. An experienced workman settled in a community in which he was perhaps born, where his folks and his wife's folks have long lived, usually requires the inducement of higher wages to move to a new locality. If the new plant finds itself unable to attract the older workers and instead uses inexperienced local labor the management pays in many ways for their training. This is not necessarily a decisive factor, but it does cause a lag in redistribution of industry. It is easier and cheaper to manufacture brass and copper goods in Waterbury, Conn., where no raw materials are locally available, than in any of the big centers of copper and zinc production in the West. It would certainly have been easier, and might well have proved cheaper, to make the equivalent tonnage of steel at one of several places in the East that is to be made at Geneva in Utah or Fontana in California. To justify these western plants, notable advantages must be shown in materials, manufacture, or markets. It is proposed herein to consider the relative importance of the more critical of these factors.

Expansion of Iron and Steel Capacity

Among the changes in the West, few foreshadow greater possible results than the doubling of the local capacity to produce iron and steel from the raw materials of the region. Iron and steel, as is well-recognized, constitute the very framework on which the body of modern industry has been built. Although a 100-percent increase in any industry is notable, it has especial significance when it takes place in the production of these materials, since such expansion opens the way to a transition from light to heavy industry and a major change in the economy of the region in which it occurs. In the present instance, this was a direct result of the war;

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the new furnaces were built to supply materials for shipyards and other war plants and to relieve the railways of a heavy burden of cross-country traffic when they needed all their facilities for other imperative work. After the war is ended it is foreseen that the present pressure of war demands on industry here, as elsewhere, will be relaxed, especially when the Panama Canal is reopened to commercial traffic and the load on the railways decreases. Then a critical situation will arise, and the permanent usefulness of the new steel-making facilities will be in question. Much discussion of this and related problems has already risen, and it has become desirable to evaluate as closely as may be the arguments that are being put forth on either side. Will it be possible usefully to absorb the new steel-making facilities into the industrial pattern of the region, or must they as a whole or in part be scrapped and charged off as a war expenditure, as it is generally conceded will be necessary to do with the larger part of the present shipbuilding industry? In a very rea sense the new plants at Fontana and Geneva are but adjuncts of this same shipbuilding industry, and they have found their major usefulness, up to now at least, in rolling ship plate. The Pacific coast consumption of th latter is now at the rate of 3,000,000 net tons[4/] a year as compared with 200,000 tons in pre-war years. Local capacity to produce ship plates has grown to 1,025,000 tons per year. The shipyards will, in large part, inevitably be charged off to war expense. It would seem to be as sound to charge off as much as may seem necessary of the new ship-plate industr

The West, though, is naturally disposed to insist that new plants be retained as integral parts of the industrial fabric of the region and tha they be operated with a view of making a permanent contribution to peace-time economy rather than wiped out as an incidental war expense. Is this feasible? Is it possible to harmonize the two points of view? These are the questions of the moment.

Use of steel, in the Western States as elsewhere, preceded its local production and has steadily kept ahead of it. From the first, mining and other machinery was fabricated on the Pacific coast and in the interior, the iron and steel themselves being shipped in from the Eastern States and to a smaller extent, from abroad. As time passed attempts were made to u local materials, and eventually a considerable local steel production was built up. It was September 7, 1881, that the first cast of pig iron (12 tons) was poured at Pueblo; that was the beginning of the activities of what is now the Colorado Fuel & Iron Co. and of large-scale western production. This beginning was inspired by Gen. William J. Palmer, builder the Denver & Rio Grande system of railways, and the Pueblo works rolled the rails and made much of the other steel which went into the building that and other western roads. Gradually, this company went into the gen manufacture of iron and steel and has for many years been the largest pr ducer west of the Mississippi River. Local foundries and machine shops were erected in the various Western States, and short-lived attempts wer made to smelt iron.

4/ Unless otherwise stated the net ton (2,000 pounds) is used throughou this report.

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The second major development of permanent importance, however, took place on the Pacific coast where, as scrap became abundant, the possibility of a steel industry based on it was recognized and open hearths and rolling mills were built at various points. This was followed in 1924 by the building of a blast furnace at Provo, Utah, which first afforded the Trans-Rocky Mountain region a local supply of pig iron. These various enterprises grew with the years until in 1938 (according to figures compiled by Iron Age) the Western States had a capacity to produce 822,800 tons of pig iron and 2,019,000 tons of ingot steel per year. Use, however, continued to outrun local production, and the West remained a heavy buyer of steel from the East, with minor amounts imported from abroad. According again to Iron Age, a particularly competent authority in this field, in 1937 the 11 Western States (Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, California, Oregon and Washington) produced or received inbound shipments of steel in various forms amounting to 2,475,000 tons, which would correspond roughly to 3,500,000 tons in the form of original ingots, so an important lacuna in supply from local plants remained. This gap, however, was being rapidly filled, and 1944 there were built or building in the region as a whole a total blast-furnace capacity amounting to 2,715,000 tons and steel furnaces capable of providing 4,655,000 tons of ingots.

Some of the various Pacific coast steel plants had been enlarged, and an additional blast furnace had been hastily moved to Provo from Joliet, Ill., and put into operation. The main additions, however, were a new integrated iron and steel plant built for the Defense Plant Corporation at Geneva, Utah, by the United States Steel Corporation and operated on Government account by the latter and the new blast furnace, open hearths, and rolling mill of the Kaiser Co., Inc., at Fontana, Calif., built largely with funds supplied by the Reconstruction Finance Corporation. Both plants are well-designed, well-built, and modern in every particular; but whatever the future may prove to hold for them, both are distinctly war babies and until events prove to the contrary should be regarded as such. It becomes an interesting matter to attempt to evaluate their probable survival against competition when the wartime demand for ship plates disappears.

COMPETITIVE FACTORS IN THE STEEL INDUSTRY

The competition the new furnaces will face will come from two sources (a) as between each other and against the coast steel plants and (b) as against the large steel plants of the East that are so situated as to permit them to ship into this territory, especially by water, materials whose manufacture adds volume to their output for other markets. Such materials require no additional plant in the eastern works but permit more continuous operation there, with all the resulting reduction in cost. Essentially, for the eastern works, it is a matter of balancing such economy in manufacture against the added cost of reaching the more distant market. Whenever the quantity of any product flowing to such market becomes more than the then surplus capacity of the works producing it the problem changes, and it becomes a matter to consider to whether to add to the existing plant at the point of the then present manufacture

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or to build a new plant at or near the center of the particular market area involved. Historically, American steel production has developed mainly on the basis of centralized production and the absorption of the added charges necessary to reach the wider market rather than building new plants in new market areas. This has by no means been entirely true, and in the long run there has been and continues to be a scattering out of centers of steel production, but the latter is a slow process and the short-time trend has been in the opposite direction.

Steel making, itself a "heavy" industry, finds a large part of its market in supplying other heavy industries; and it is a fact easily to be read in economic history that periods of plant expansion are irregular, or at best rhythmical, rather than steady and persistent. From this follows the well-known fact that the steel industry is alternately "prince" or "pauper." A steel company from time to time either makes a lot of money or struggles to keep its head above water. One reason for this, although it is not always easy to be sure which is cause and which effect, is that the mechanics of steel-making is such that large-scale plants, if they can be kept in continuous operation, are so economical they have enormous advantages in cost over any less well-equipped or less fully integrated competitor. In production by a large modern blast furnace or that of one of the new continuous strip mills, the largest element in cost is usually the degree of continuity of operations. In most industries the wages of labor constitute the largest element of cost of output, but in operating a modern blast furnace it may be as little as 5 percent. This, though, is only true when operation at full capacity is possible. At part capacity the economies flow away, and in periods of stagnation in business and limited demand for steel the small, specialized plants have the advantage. It is not economical to use a sledge hammer to drive a tack any more than it is to use a tack hammer to drive a spike.

In fixing the location of a blast furnace, it is customary to consider the cost of assembling raw materials for the blast furnace as the determining factor. By reason of the economies incident to the use of hot metal in making steel and those flowing from the use of the waste heat and of surplus coke-oven gas and blast-furnace gas, modern steel works and blast furnaces are generally built as integrated units. As a general rule, too, the ore flows to or near the coal fields rather than the reverse. Other matters must be taken into account, though generally considered to be, sometimes erroneously, less important. Of these secondary considerations, the market for the products and the presence of a supply of scrap iron and steel are outstanding. Limestone or dolomite is needed for flux, and occasionally silica must be added. Manganese and other materials must also be supplied but in amounts relatively so small that if necessary they can be shipped to the works from a much greater distance than is permissible for either the iron or the coal. A large quantity of water is needed, as well as coal and iron, so an adequate water supply is very important. As the weights involved, especially in the case of blast furnaces and stock piles are large, the provision of sturdy foundations is a self-evident necessity and a plant site must be chosen with care. It is obvious that, considering the tonnage that flows into and away from a steel works, adequate and suitable transportation facilities are of primary importance. Finally a successful works must have sufficient capital and reserve financial support to

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ry it through a lean period and must be in a district where there is, · can be attracted to it, a considerable labor force.

Of the raw materials necessary, 2 tons of ore of the present generally rchantable grade is required, as a rough general average, to make 1 ton pig. There are also necessary approximately 1.6 tons of coking coal d about one-third to one-half ton of limestone for fluxing the ore. On e basic of 1,000 tons daily output - a common figure for a modern blast rnace - this works out to about 4,000 tons a day incoming and 1,000 tons tgoing freight. To amortize such a plant in the 20 to 25 years which the rning power of money and the progress in technology indicates to be a nservative period, a reserve of some 20,000,000 tons of ore and nearly a rresponding amount of coal is needed.

To convert the pig iron into finished steel there will be required, the basis of current American practice, as much scrap metal as pig iron rough the widest variation is possible in this ratio, depending on the lative availability and local price of each. Steel has been made from rap or pig alone; but usually they are employed together, and there are hnical as well as financial advantages in using them so. A modern inte- ated steel plant itself generates a considerable portion of the scrap ich it uses, the actual amount depending materially on the degree of manu- cture to which the output is carried. In general, of the amount of steel st into ingots about 30 percent returns to the furnace as recycled scrap. rap recycled within an integrated plant constitutes what is known as home rap. To this is added outside or purchased scrap, usually an amount ualing two-thirds to all of the home scrap. If the local price of scrap s low, more is used. A minor amount (5 to 6 percent) of best-grade ore y be used in the open hearth and so may get into the steel without having ne through the blast furnace.

Having in view the great weight of raw materials used, attention has en perhaps unduly focused on their situation with reference to a proposed rnace site. It is clear that, so far as steel making alone is concerned, e scrap market may well be equally or more important. It must also be ear that the density and accessibility of the market are very important ctors and may of themselves determine the location. One of the plants at competes effectively for business in the markets of the Pacific coast s that at Sparrows Point, near Baltimore, Md. Coal and iron must be ipped to this plant from more than average distances, the quantity of rap locally available is not larger than at various other points, and the arby market is not strikingly large. In this instance the success of the rks is due primarily to the management it has enjoyed and to its position n one of the great Atlantic harbors, giving it access by water to all astal and foreign markets.

So many factors enter into the success of a steel plant that it is cessary to be a bit cautious against overemphasis on any one or two in stimating its success. Making and selling steel is a business, and the les of business both as to buying and selling apply. No more in it than n other business is the output sold at cost or at a fixed percentage over ost. There is a legitimate cost of selling to be considered, and in practice

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there is a wide margin between the cost of the assembled raw material and the market price of the steel. The cost of materials is an important, and may be the determining, element in choosing a site for manufacture, but even a serious handicap in this particular may well be overcome by other less apparent factors.

TECHNICAL ASPECTS OF WESTERN STEEL-PLANT OPERATION

The future of the new steel works in the Western States must be considered against such a background. To reach sound conclusions it is necessary to determine the answer to such questions as the following:

1. Are the raw materials - iron, ore, coking coal, limestone, and scrap - present in such quantities and of such grade as to permit assembly at otherwise suitable sites at a cost reasonably near that of the cost at competitive works?

2. Does the present or reasonably sure future market, either in the region itself or within competitive accessibility, warrant production of enough steel, in the various individual forms proposed, to permit operation of units of manufacture of sufficient size for effective competition with companies now selling in the territory?

3. Do the conditions of manufacture as to plant, supplementary fuel or power, labor, water, etc., permit manufacture at a competitive conversion cost?

4. Are the plants soundly financed, and have they back of them adequate financial reserves to permit the managements to last through the periodic lean periods that have up to now characterized the history of the American steel industry?

Raw Materials

Iron Ore. - The first essential to making pig iron is obviously iron ore. It may be said at once that the known and prospective reserves of iron ore in the Western States as already defined are distinctly small compared with those in other producing regions of the United States. E. F. Burchard, of the Federal Geological Survey, has summarized the situation as below. His wide familiarity with iron ores and his long contact with the subject attach particular weight to his opinion.

Iron-ore reserves of the Western States

	Long tons	
Measured and indicated	141,050,000	
Inferred	272,612,000	
Potential	141,197,000	
Total		554,859,000
Total production to end of 1943	38,200,000	

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For comparison, Burchard's estimates for the Northeastern States, - Ohio, Pennsylvania, New Jersey, New York, and New England - which have recently come in for reviewed attention, may also be quoted as below:

	Long tons
Measured and indicated	535,327,000
Inferred	389,360,000
Potential	1,466,049,000
Total	2,390,736,000
Total production to end of 1943	162,000,000

As is well-known, the present and prospective reserves in the Lake Superior region and in the Southeastern States are much larger than either.

Many individual western iron-ore deposits from the Canadian to the Mexican border have been studied in detail by various agencies. The known information regarding them has been summarized in the Miller[5] and Hodge[6] reports and in an earlier one by Daniels.[7] It is hardly necessary to review the data here since the reports cited are available in numerous public libraries.

In the search for war materials the Geological Survey has restudied many of the deposits, and the Bureau of Mines has drilled a number. From all these sources of information the conclusion has become clear that in the entire western region there are only three districts from which sufficient ore can, with any reasonable assurance, be expected to supply a modern steel works through or beyond the necessary period of amortization. These are the Sunrise mines in Wyoming, the Iron Mountain mines in southwestern Utah, and the Eagle Mountain mining district in southern California. Other mines have supplied ore in important supplementary amounts, such as the Orient mines in Colorado, the Fierro mines in New Mexico, and the Vulcan mine in California, from which last the Kaiser works now draws its supply. Still other deposits, such as those near Dayton in Nevada and perhaps others in Washington and Oregon, can be counted on for supplementary supplies; but when it comes to districts in which there is assurance of enough ore to support a modern furnace through to amortization, the choice narrows rapidly to the three already indicated. It is always possible that future prospecting or improved technology may change the picture, but in the light of present knowledge there is no reason to expect the West to be able soon to

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support many if any more blast-furnace plants than have now been built. more are erected, their main reliance must necessarily be upon imported o and the possibility of obtaining such ore now is by no means clear. At leas three localities on the West coast of Mexico can be called upon, if need be, according to reliable reports. Other deposits along the Pacific coas in Chile particularly, are worth consideration as prospective sources of supply, so that when need arises and output justifies the necessary capit investment, ore can be brought in to feed Pacific coast blast furnaces ju as at Baltimore, where at various times Chile, Cuba, North Africa, Austra and Spain have been drawn upon. The trans-Pacific countries can supply o to West coast furnaces, if the demand warrants the cost. So far, however such iron supplies as have come from China and India to the United States have arrived in the form of pig iron, and future shipments would seem lik to be in the same form because of the cost of transporting ore. If large drafts on trans-Pacific sources of supply come to be made, nodulized iron may be brought in.

The iron ores used in western blast furnaces are mixed hematite and magnetite. They average a little better in metallic iron (53-56 percent) than the bulk of the ore used in the East and are low in silica. In fact it has been necessary at the Provo furnace to add silica rock to the furnace burden at times to make a large enough volume of slag to carry off t sulfur present. The phosphorus content is not unfavorable, but sulfur is present in quantities that require constant care, all the more so since i is distributed irregularly. Another problem is the occasional presence o zinc and of rather high alkalies, both of which cause trouble with the furnace linings. In general, however, the ores used by the western blast furnaces are of good, workable grade, not so high in iron as those mined in the Northeastern States and notably higher than the main bodies of ore used in the Southeast. They compare well with the Lake Superior ores, ex cept that the latter are more regular in physical and chemical composition and are low in sulfur. Perhaps when the western mines come to be operate on a larger scale this difference will disappear. Meanwhile, at the Geneva Fontana, and Pueblo plants excellent bedding systems have been put in to regularize the grade of ore going to the furnace.

The percentage of lump ore is low, and a considerable part of the o is screened out and sintered before being fed to the blast furnace. Inde sinter forms 30 to 50 percent of the ore in the furnace feed. One factor which encourages this practice is the high percentage of undersize in the coke, for which there is neither the market as domestic coke that so frequently favors the eastern furnace nor need for it as fuel for making ste in view of the volume of recoverable waste heat and of plant-generated or cheaply purchased gas available. At all western works, also, fairly chea hydroelectric power is available. From all this it follows that the easy way to handle the fine ore and small coke, and at the same time lower the sulfur content, is through a sintering plant, despite the fact that sinte ing adds to the cost.

Except at Sunrise, Wyo., where mining is now passing over into unde ground operations, the western ores are won by open-pit methods with powe shovels and, in the newer operations, truck haulage in the pits. These

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methods make for low-cost operations, and in the cost of the iron ore at the furnace the railway haulage forms the largest element. The distances are fairly long as such matters go in iron mining, and in contrast with the blast furnaces in the Pittsburgh and Middle West area, the movement is all rail. From the iron mines to Provo the distance is 240 miles; from the Vulcan mine to Fontana about 175; from Sunrise to Pueblo about 360. At present the Colorado Fuel & Iron Co. is drawing part of its ore supply from the Iron Mountain district in southwestern Utah, over 820 miles away. The distances over which ore travels to eastern and midwestern furnaces, except in the Birmingham district, are usually much greater than any but that last quoted, but the movement is largely by water, where the cost per mile is approximately one-tenth as much. As Mahoney has already pointed out,6/ the Lake Superior ores traveling from the Mesabi range to Pittsburgh must be hauled by rail from mine to lake and from lake to furnace, a total distance by rail of about 210 miles, but little less than that from mine to furnace in Utah. In addition, the Lake ores must meet the cost of lake transport (837 miles), with the added charges for loading and unloading. The rail freight rate from Sunrise, Wyo., to Pueblo, Colo., is $2.75 per gross ton compared with a lake freight rate of $3.02 from the Mesabi range to Pittsburgh, Pa. Recently an ore movement from the Adirondack region in New York to the Ohio furnaces has been built up, which requires shipment of ore more than 500 miles by rail. In this instance, as in that of the long water-haul from Chile to Baltimore, there is compensation in the markedly higher grade of the ore, so that the freight cost per unit of iron is not prohibitive. It would appear that, so far as the western blast furnaces are concerned, the distance ore must travel from mine to furnace is not out of line with that of competing plants. The Fontana plant is relatively near the iron mines on which it will draw but is 810 miles from the coal mines. It is a striking exception to the general rule already cited that iron ore moves to coal rather than the reverse, but the location of the Fontana works was determined primarily by nearness to market and access to the sea, the same factors that have contributed so greatly to the success of the Sparrows Point works at Baltimore. At present Fontana draws its iron ore from the Vulcan mine, 170 miles away. Its long-time reliance will be on the Eagle Mountain deposits, only 145 miles away. The distance is relatively short, and the low cost of iron ore at the furnace is counted upon as one of the permanent advantages of the Fontana plant.

Coal. - The second most important if not indeed the outstanding raw material for making pig iron and steel is coal. This is needed not only for generating power and heat but for coke (the special form of fuel used in blast-furnace operation) which is made from coal by carbonization in special furnaces or ovens. In coke making the larger part of the volatile matter in the coal is driven off in the form of gas, about 40 percent being burned to heat the ovens themselves and the remainder becoming available for other uses. The residuum of the coal, corresponding to the fixed carbon, is left as a porous, spongy mass of high heat value. In the course of the process, part of the volatile is redeposited on the cell walls of the coke. Strength is

6/ Mahoney, J. R., The Western Steel Industry: Utah Econ. and Bus. Rev., Salt Lake City, Utah, June 1944, vol. 3, No. 1, p. 16.

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an essential property, being required because the coke itself is to be mixed with iron ore in the stack of the furnace, which is usually 90 to 110 feet high; the coke must, accordingly, sustain considerable weight without crushing. In the furnace the coke is burned to carbon monoxide, giving off high heat, and the carbon monoxide passing up through the mas of ore above robs the iron ore of its oxygen, reducing it to metal. The mixture of carbon monoxide and carbon dioxide, together (unfortunately with dust), is drawn off from the furnace, cleaned, and burned further to preheat the air for the furnace or is used for other purposes.

The process is by no means as simple as this, and many supplementar and side reactions take place, but the essential fact is that raw coal i changed by treatment in coke ovens into a strong, porous material, still high heating value. In making coke, various valuable byproducts are now recovered; under favorable market conditions these are sold and afford a credit on the cost of coking or even wipe it out altogether. This is an important matter to be considered in deciding on a location for a steel works, because a plant in an industrially mature region has an advantage in the marketing of the various byproducts. Where no market exists or i poor, the recovery of the byproducts is not attempted, but the gas is us only as fuel. Since, however, this is wasteful and only strongly coking coals can be successfully coked in old-style beehive ovens to yield a go furnace coke, the spread of the industry into new districts where new ov must be used, as well as the potential profit from sale of byproducts, h led to almost universal adoption of the newer-type ovens. To meet the w emergency, the beehive ovens were brought back into service in districts where suitable coals were available, but this was not always successful aside from the economic waste involved. The attempt to use beehive-oven in the Defense Plant Corporation blast furnace at Provo was, for example a complete failure, and as the byproduct ovens available were not numer enough to supply coke to both the old and new furnaces, the Defense Plan Corporation furnace was closed down.

As has been intimated, not all coals can be coked successfully, eve in modern ovens. The higher-volatile coals usually must be mixed with c to secure a satisfactory yield of blast-furnace coke. Unfortunately, th high-volatile coals only are abundant in the West. Although the largest reserves of coal in the United States are in the Western States and are potential basis of an enormous release of energy in the years to come, t proportion of coking coal in the West compares very unfavorably with tha in the East. The total coal reserves of Utah is nearly as large as that Pennsylvania, but the latter includes a large percentage of good coking coal, whereas in Utah only a small part of the coal is known to be of co quality. Of the coals used in byproduct ovens, eastern coals yield 71.5 percent of coke, excluding the breeze, while in Utah the yield is but 5[illegible] percent, so that not only is the amount but also the yield of coking coa the West low. Next to Colorado, Utah holds the largest reserves in the West, and the present and prospective large use of coal in steel product is of Utah coal. In Washington there is coal which yields a harder coke after it has been washed; but the reserve is small and the mining condit difficult, and it seems improbable that the coal will have more than loc and limited use.

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In modern byproduct-coke making, it is customary to mix coals of different qualities to overcome the defects of the one that constitutes the major source of supply. Coke for eastern furnaces often is make from a mixture of high-volatile coal with a low-volatile, such as the Pocahontas. By varying the mixture and the design of the furnace and by suitable operating procedure it has proved possible in various parts of the world to produce a satisfactory furnace coke, even where main reliance must be on a coal of moderate or feeble coking tendency or one that produces a weak coke. In Colorado this is being done. At Fontana experiments are under way to improve the coke made from Utah coal alone by mixing in a percentage of low-volatile coal shipped in from Oklahoma. Technically the work has been a success, but whether or not the improvement warrants the added expense is not yet determined. In Colorado, where no adequate source of low-volatile coal is at hand, experiments have been made substituting an artificial product made from high-volatile coal by low-temperature distillation.2/ The desired increase in quality of the coke was effected, but the project failed owing to lack of satisfactory local market for the particular byproducts of the process, and perhaps to some degree to the relatively high cost of manufacturing the artificial low-volatile coal. At both plants the pitch, which is the end product after distillation of the lighter oils from the main coke ovens, is returned to the ovens to help increase the coking quality of the coal.

Byproduct coking in Utah was begun in 1924, when Columbia Steel started the furnace at Provo. Certain deficiencies in the resulting coke were anticipated, and every known means was employed to adapt the ovens to the coal so as to secure a satisfactory yield and quality of coke. It was found that the resulting coke could be used, although the yield of furnace-size pieces was low compared with that usual elsewhere. It remains low despite continuous and careful research throughout the 2 decades since. In 1943 only two-thirds of the gross coke yield could be sent to the blast furnace, although the actual coke:iron ratio in the furnace itself has been better than average. It is not only that the quantity of breeze or very fine coke is high, but the quantity of intermediate size that would normally be sold as domestic fuel or burned in a power plant is high also. This same problem must be faced by any blast furnace depending on western coal, so far as present knowledge goes, although it is to be hoped that the size of the problem may decrease as more experience is gained. Economically it would not be so serious if a good market for the off-size coke could be found, but in southern California cheap natural gas is available for domestic fuel and both there and in Utah hydroelectric power is sold at rates that discourage sale of the coke for producing power. The Provo furnaces cover the existing market in foundries, nonferrous smelters, and minor uses. There should be a good market in Salt Lake City for the coke from both Provo and Geneva for domestic fuel, but apparently householders would rather enjoy the smoke from local coal than change their habits. A limited quantity of the coke can be sold to the nonferrous smelters of the Salt Lake Valley,

2/ Price, J. D., and Woody, I. V., Production and Use of Low-Temperature Char as a Substitute for Low-Volatile Coal in Production of High-Temperature Coke: A.I.M.E., Tech. Pub. 1745, 1944.

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since they do not require a coke of great strength, their stacks being lo and they can use coke higher in sulfur and ash than iron blast furnaces. In general, the answer to the problem has been found, for the present, to be in crushing the fine coke and using it in sintering fine ore, as alrea indicated. In the local situation faced by blast-furnace operators in th West, the unsatisfactory character of the coke is, as regards raw materia the weak point. It is especially difficult because of the absence of a supply of low-volatile coal for mixing in. Even where high-grade coking coal is available, as in the Pittsburgh region, the advantages from mixin in a fixed amount of low-volatile are so great that the practice has now become standard. It is to be expected that technical progress in coke making will in time overcome the present difficulty, but the past 20 yea experience does not afford the assurance of this that one would like to report.

Sulfur has been mentioned as one of the difficulties, and since it i irregularly distributed in the ore and is also present in the coal it mu be constantly watched; but it is an annoyance rather than a major diffic At the Geneva plant the coal and coke are now reported to be running as below in percent:

	Sulfur	Ash
Coal	0.85	6.5
Coke	.72	9.5

This is by no means bad, and if the structure of the coke could be improved and the yield of furnace size increased there need be no diffic In the absence of this improvement, blast-furnace operations face a certa handicap, though not one that will put the companies out of a competitive position.

Flux and Alloy Materials. - Good-quality limestone is widely distri uted, and at none of the places at which blast furnaces are operated, or even any at which other furnaces have been proposed, is any insurmountabl difficulty as to supply at reasonable cost likely to arise. The same condition applies as to manganese and other minor constituents of modern steels. This is all the more true since, even in case of the limestone, the tonnage involved is not great. The alloying materials are used in v small amounts and are generally added in the open hearth or ladle in the form of ferro-alloys separately prepared. In part they are made in elec furnaces and in part in blast furnaces set aside for that purpose or in special runs in one of the regular blast furnaces. The main market lies the East and Middle West, where the big steel-making industry is situate and the quantity of any of them, except manganese, needed in the West is very small. Since around the world each steel-producing country makes i own ferro-alloys, there is small chance of developing a foreign trade. I the West as a whole it therefore becomes a problem of competition - whet the cheaper electric current in the West will overcome the cost of shipp to the East plus the economies, such as they are, of larger unit product in blast furnaces. This is a practical problem in production and market to which no answer is yet apparent, but it is well to remember that pro uction has a very strong tendency to persist at or near the points where

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has been first established. Nonetheless, local ferro-alloy manufacture commensurate with whatever the local steel manufacture may come to be can be safely predicated.

Scrap. - In general, about half the steel now turned out by steel furnaces is made from scrap and half from pig iron. In 1945 steel mills, blast furnaces, and foundries in the United States charged 61,650,956 net tons of scrap and 60,315,159 tons of pig iron. For the country as a whole, therefore, the ratio of scrap to pig in the furnaces and foundries was 51:49. The actual ratio varies as between furnaces in different parts of the country and from time to time, depending on availability and relative prices of pig and scrap. Either can be used, and the choice is based almost entirely on price. In the past, scrap has been at once more abundant and cheaper in the Western States than pig iron, so that it has been used in greater amounts, furnaces having indeed been operated on scrap alone. In the country as a whole, pig iron has been decreasing in importance, and for some years more and more steel was being made with less and less pig iron. Steel, once made, is to a large degree recoverable after use, and the total amount in use increases as the years go by, so that a veritable reservoir of scrap and potential scrap is being built up. No certain answer can be given as to how large this reservoir now is, but it is certainly large and still growing. In earlier years, when the railroads were the largest users of steel, the cycle from production of steel through use to recovery and remelting was about 20 years. In other words, the scrap returned to the furnaces in any one year corresponded roughly to that the steel produced 20 years before. The cycle is now shorter, since the largest consumer of steel through recent years has been the automobile industry, and automobiles wear out faster than railway equipment, partly because of the service required and partly because so much of the steel is put into thin sheets rather than heavy sections.

To make steel from scrap requires a smaller investment in plant than when pig is used, since the process does not require a blast furnace, one of the largest and most expensive units in an integrated plant. It is not unusual therefore for steel manufacture in any region to begin, as it did in the Pacific Coast States, with plants that use scrap only. As these create a demand for that material and in consequence the price rises, it becomes economical to introduce pig iron and a supply is called for. In time relations, therefore, use of scrap in any district is apt to precede use of pig, despite the fact that the latter is the more fundamental material.

Not all the steel that comes out of the furnace goes into use and after a time is available to be remelted, refined, and reshaped. The very process of steel making itself yields a large amount of scrap, which never goes out of the plant but forms a revolving load. In the year 1943, for example, of the total used 35,037,088 tons was so-called "home" scrap and consisted of the pieces trimmed off or discarded in manufacture. The "purchased" scrap - that is, the steel that had been in use and had to be gathered up and brought back - was 26,613,868 tons. Since the carbon steel poured in 1943 totaled 75,686,694 tons and the yield in hot-rolled products was but 55,884,676 tons,

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the home scrap produced was 19,802,018 tons or about 26 percent of that poured. For alloy steels the amount poured was 13,149,818 tons, the yiel in rolled products 7,407,997 tons, and the scrap percentage nearly 44. For a term of 5 years the quantity of home scrap produced in the United States equaled 26.9 percent of the ingot output. It is well to keep in mind the important place scrap occupies in steel making. If the steel maker had always to start fresh with ore, approximately 2 tons of the later would be needed for every ton of steel produced. In general, since the proportion of pig iron to scrap in open-hearth furnaces is about 1:1, 1 ton of ore and not 2 tons is used to produce 1 ton of steel. This redu the quantity of freight that enters into the calculation of cost of assembling raw materials, as scrap usually originates at or near the steel works; moreover, the heat units needed since melting down scrap involve less heat than when pig is made from ore. A location therefore in a high industrialized district, where scrap tends to accumulate, may be as favor able as one nearer iron mines.

This reason shows why the ore usually moves to coal rather than the reverse. The presence of coal in any district favors establishment of ma facturing there and not only makes a local market for steel but builds up a supply of purchasable scrap for the steel furnaces. When attention is focused on pig-iron production this is less likely to be true, since scra is not ordinarily fed to blast furnaces in any large amount. Scrap is ad to the furnace burden only when it is desired to increase the furnace out temporarily. As most of the scrap used is already suitable for melting down in the steel furnace, putting it through the blast furnace first is rarely profitable.

The choice of location for a steel plant is much wider than for a bl furnace since coke is not needed and any good fuel can be made to serve. Cheap coal, gas, or oil and cheap power from any source are sufficient if scrap and market are available. It has already been stated that steel ma in the Pacific Coast States began with relatively small mills in or near Los Angeles, San Francisco, Portland, and Seattle. As demand increased, moderate market for pig iron came into being, and Columbia Steel built it furnace at Provo. When the war created in the West an immense demand for shipbuilding materials, additional blast furnaces were built, and new ste furnaces were erected near them to secure the benefits of unified manage of hot metal, and of better economies in the use of fuel inherent in the surplus gas generated by the coke ovens and the blast furnaces themselves The plants were made large to procure the benefit of low costs incident t large-scale production. The annual capacity of the Defense Plant Corpora plant at Geneva, Utah, is 1,300,000 tons of open-hearth steel. The three blast furnaces there are designed to produce 1,149,000 tons of pig iron. Evidently little purchased scrap is to be used. At the Fontana plant of the Kaiser Company, Inc., the one blast furnace is designed to produce 431,000 tons of pig iron and the open hearths 700,000 tons of steel. Bef the war, the ingot capacity of California was 850,000 tons and of Washing 174,000 tons. All this steel was made from scrap except for the pig iron supplied by the single furnace at Provo, which had an annual capacity of 204,300 tons. The quantity of scrap available in the United States was, however, so large that in the 3 years 1938, 1939 and 1940, 4,906,073 tons

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was sold abroad for shipment to Japan alone a considerable part of which was drawn from the Western States. These figures illustrate the importance of scrap in the local field of steel making.

Fuel. - In the production of iron and steel, both heat and power are required in large amounts. To a certain extent, the two are interchangeable. The waste heat from the furnaces can be recovered and used for the generation of power, or hydroelectric power may be employed to generate heat in an electric furnace and so reduce iron from ore or refine steel from pig or scrap. The surplus gas from coke ovens and blast furnaces may be used to carry on the process of manufacture or may be sold and purchased power or cheaper fuel substituted in the steel works. In an integrated plant the gas which is necessarily made in the coking process, together with that from the blast furnaces, is adequate to furnish heat and power for all the work done up to where rolling begins. To that point heat rather than power is needed. Beyond that point, power rather than heat is required. It is one of the odd compensations in industry that the surplus gas necessarily produced in the fundamental process of making pig iron should be correct in quantity and quality to furnish both heat and power to convert the pig, or hot metal, into steel. If it is not so used it must be wasted or an outside market found for it. The coke-oven gas is sufficiently high in British Thermal Units to find a wide market, and at a considerable number of plants it is sold for domestic heating at a price higher than would be required to buy substitute fuel for use in the steel plant. At some plants producer gas is so substituted. At others natural gas, petroleum, or powdered coal is employed, or electric power may be purchased for blowing engines and incidental purposes.

The tar made as a byproduct of coking may be burned in the open hearths or it may be sold, as works out best in each instance. One objection to selling the surplus coke-oven gas is that it frequently makes necessary location of the blast furnace nearer the city to which the gas goes than might otherwise be desired, because of the cost of transporting relatively low grade gas, although this is not a large difficulty. In the Ruhr district a network of pipelines collects surplus gas from coke ovens and blast furnaces, much as in an American oil field. Byproduct recovery plants have been placed at central points, from which the stripped gas is delivered to the cities of the region. The main objection to the sale of gas is that which must always be taken into account when entering any byproduct field - demand for various products does not always rise and fall at the same rate and time. In periods of depression blast furnaces have been compelled to run and make pig iron for which there was no market because of a contract for delivery of gas to some nearby city or gas company. As a general rule, it has seemed to work out better to combine blast furnace and open hearths in one plant, use the surplus gas in the steel furnaces, and conserve heat by employing hot metal rather than to remelt cold pig in the open hearths. The economies resulting from use of hot metal are real and large, although steel makers forced to use cold metal have found ways to reduce their handicap. By changing the composition of the gas used in the open hearth, mainly by making it denser, the warming up has been speeded until total time in the operation is not much longer than that desirable in any event to allow the reactions to take place. While, therefore, the argument based on economy

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from use of hot metal is not so compellingly favorable to integration of coke oven, blast furnace, and steel plant as it was formerly considered to be, it remains true that manufacture of steel is one of the best ways to use the surplus gas from the pig-iron-making part of the combined general process. It is seldom that wholly satisfactory use of the gas can be made in any other way. Its use ties the whole process together and gives steel making its cheapest possible source of heat and incidental power. One other factor to be kept in mind is that since, in any event, coal must be at hand to produce coke, any additional heat needed for reheating furnaces of power for shaping the steel usually can be cheaply supplied by burning more coal or making producer gas.

Electric Iron and Steel

It is technically feasible to make pig iron from ore in an electric furnace, although it has seldom proved economical in practice. So far as experience goes, use of the electric furnace for this purpose is only justified in particular areas and under special circumstances. It has been urged on the basis that since such a furnace uses coke as a reducing material only and not primarily as a source of heat, it may well be chosen in districts where coke is scarce or unduly expensive. The further advantage is urged that since the electric furnace is smaller a plant to produce a given tonnage is more flexible than one that depends on a blast furnace. It would, for example, require 10 of the largest electric furnaces to yield the output of 1 modern blast furnace turning out 1,000 tons a day. A blast furnace gives its best results run to capacity on a full-time schedule. When it must, because of market or other conditions, be operated below capacity or intermittently the cost per ton of output rises steeply. Obviously, the ability to cut production by 10-percent steps and operate the remaining plant at full capacity would be a considerable advantage in an electric-furnace plant; however, this is offset by other factors. The 10 smaller furnaces will require more labor per ton of output than the 1 large one. The heat losses will be greater and the capital investment, while lower, is doubtfully so if the investment in power plant is adequately taken into account. Recovery of top gas is lower, and while the gas is richer than that from a blast furnace it is not enough so to change the balance. The electric furnace also used carbon in a markedly expensive form in the electrodes. While, therefore, the quantity of coke used per ton of pig iron is lower than in a blast furnace, possibly as much as one-third, the actual consumption plus loss of British Thermal Units, translating current back into the latter, is more nearly in ratio of 27:30 than 1:3. Calculations made to correspond with western conditions, allotting to each the same coke and ore at the same price per ton, indicate that with normal amount of lost time for relining and similar operations, pig-iron costs would be in the ratio of $20 per ton for electric-furnace production as compared with $16 for pig iron from a blast furnace. The actual costs would depend on many items, such as the particular raw materials, the particular site selected, and others. It is the ratio that is significant, and it is hardly likely that it would be upset in any important degree by any manipulation of these factors, which happen to be open to western operators. For the electric furnace the most important factor is the cost of current. For the blast furnace the critical factors are, first, size and second, continuity of operations. At each plant the opportunity for profitable use of the top

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gases is important, especially in the case of the blast-furnace plant because the percentage of recovery is higher and heat losses less.

This matter has been much discussed in view of the large hydroelectric plants built and planned by the Government in Washington and Oregon. It will obviously be some years before the total power available will be needed for domestic and general use. Further industrialization will be required to make a market for the power. The metallurgical industries are naturally to be considered, as they are large users of power, in particular in the production of metals and alloys. At present a considerable amount of the new power is used in or allotted to production of aluminum, magnesium, and electric steel. The power requirements per pound of metal produced are, for these three, as below:

	Kw.-hr.
Aluminum	10.00
Magnesium	8.00
Steel	.25

When the war ends there will be a period at least in which there will be markedly less demand for either aluminum or magnesium than the present capacity of the country to produce it. Probably there will be at the same time a dropping off of the demand for alloy steels, in which field electric furnaces have found a special usefulness. In 1943, 4,589,000 tons of electric steel and 13,149,800 of low-alloy steel were made in the United States. A decline in production has already begun. The field however is large and through the years has been increasing steadily. A decline in demand for ferro-alloys is also to be anticipated, and although the more common types are generally made in blast furnaces, electric furnaces are also being used. The drift toward higher-grade steels is unmistakable and seems certain to continue. Tailor-made quality is best secured by using an electric furnace where conditions can be closely controlled and where small lots may be made to meet particular specifications. For the carbon steels, and when quantity production is required as is now true of low-alloy steels in general, the open-hearth furnace will be preferred. This will apply even in the Northwest, where cheap electric power is available, since it happens that there and all along the coast petroleum, an almost ideal fuel for use in the open hearth, is also cheap.

The situation in the West therefore, even in the States where electric power is expected to be most abundant and lowest in price, favors a development of existing practice rather than any radical change, that is, continued production of pig iron in blast furnaces and of the bulk of the steel in open hearths. The scrap now used in the latter will be supplemented by an increasing quantity of pig as scrap becomes scarce or rises in price and as the natural demand for steel grows. The electric furnace will find its field in making special steels and alloys.

It is interesting to note that substantially this same conclusion has been reached by Raymond M. Miller, consulting metallurgist for the Bonneville Power Administration, now that the plants of the latter are in operation and rates have been announced. In the latest edition of his report on the

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feasibility of a steel plant in the Lower Columbia area[10/] after comparing costs and efficiencies, he states,

> Obviously then, use of the electric furnace in the Portland Area would be confined to the refining of steel for producing the higher grades of steel and steel alloys, as is done in other sections of the country. No further consideration need be given to the electric furnace except as auxiliary equipment.

Sponge Iron

Alternative to the electric method of making steel in numerous small plants to utilize local materials and disperse the industry, manufacture o sponge iron is sometimes urged in place of blast-furnace production of pig Considerable misapprehension exists as to this, and it may be helpful to review a few of the features of the case. Making sponge iron is the oldes form of iron manufacture, but with evolution of the primitive plant into the blast furnace it has been all but abandoned as a separate step. In th operation of the blast furnace, sponge iron is made by direct reduction of the ore by the uprising gases. This sponge iron is then melted down to pi in the same furnace with conservation of all the heat it then holds, the impurities being slagged off as liquid in the simplest manner possible, an with a loss of iron of less than 5 percent. It is a continuous process which conserves heat, byproducts, and labor, with a total economy impossib to achieve in any other method as yet known to metallurgists.

The arguments are frequently offered that, since the various spong-ir processes can be carried out without coke they permit use of other fuels and so broaden the base of manufacture, and that iron ores can be used which are not amenable to blast-furnace treatment without expensive treat-ment. Some truth lies in these arguments, but it is an old though hard ru of economics in technology that high-grade products cannot be made from low-grade materials except at higher cost. In the case of sponge-iron pla that have been operated or have passed beyond pilot-plant stage, it has s far proved true that there is a disappointingly high protion of intermedia product that must be returned to the furnace. The economy of operation h also yet to be proved, since few plants have been run beyond the experime stage. Both the Germans and the Japanese are now using the Krupp-Renn process in a few small furnaces, but in each instance it is to meet a special situation and is a supplementary operation. Moreover, there has been no evidence of a disposition to substitute it for blast furnaces. Wi all their acknowledged skill and with every inducement to do so, the Germ have never been able to bring sponge-iron making beyond this stage. The Swedes have possibly gone farther, as they have in electric furnace manu-facture of pig iron, but in each they operate under the exact antithesis o the conditions urged in the United States for going into the business. Th is, they use only the highest grade of materials to make a special produc some of which, as it happens, is imported into the United States. Here, a

10/ Miller, Raymond M., An Investigation of the Feasibility of a Steel Plant in the Lower Columbia River Area near Portland, Oreg.: Orego Dept. of Geology and Mineral Industries, Bull. 8 (rev.) 1940, p. 53

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n Europe, there may well be a minor place for sponge-iron processes to anufacture particular products, but even this is open to some question s to whether sound economy would not rather point to continuation of esent methods in most cases. It is hardly necessary to repeat here the gument against to great reliance on small units already offered in con- dering the making of electric pig iron.

Advantages of Large and Small Plants

The many advantages of large unit plants in making pig iron and steel, at least to the point where it must be formed into shape, make it im- acticable to look forward to effective competition by small, scattered lants based on use of electricity. To the extent that small units can nd a place, it will be in the manufacture of steel, where there is undant scrap and low-priced fuel. This condition already obtains on he Pacific coast where, before the Fontana and Geneva plants were built, ix mills that ranged in capacity from 75,000 to 200,000 tons were producing ast a little less than 1,000,000 tons of steel per year. In addition, one lectric-furnace plant produced 15,000 tons. These small plants were re- ponsive to the natural conditions of the region; they had, and will con- inue to have, a soundly based position in its economy. The two new plants re planned to produce 1,581,000 tons of pig iron from which to make 2,000,000 ons of steel per year. It remains to be seen how rapidly they can make a lace for themselves, but in any event there is no reason to believe that he ultimate pattern in the West will differ materially from that now ob- aining in other parts of the country, namely, large central plants for he fundamental and major steps of production, supplemented by a number of mall, widely distributed steel manufacturers of specialties or operating nder special conditions such as the rerolling plants in various parts of he country. Both large and small steel plants have their place in industry. n 1943, 140 plants made steel for rolling or casting in the United States. f these 65 produced less than 250,000 tons each. In contrast 41 of the arger plants had capacity for production of from 800,000 to 5,000,000. The arger part of the steel produced in the United States comes from the big ntegrated plants, but both large and small works find a place.

The manufacture of articles out of steel rather than the making of teel gives the small plant its greatest usefulness and affords opportunity or expansion and profit. Incidentally, it is in this segment of the field f manufacture that the largest amount of labor is employed. Approximately ive times as many men per ton are employed in fabricating steel as in making t. If the process of steel making is followed clear back to the mining of he raw materials for the blast furnace the ratio is still nearly 4-1/2:1, o that it is to fabrication and further processes of manufacture that the orthwestern States would do well to look for benefits from their power develop- ent and in the effort to secure the social benefits of a wider distribution f industry. In this they would have the great advantage of applying the ower direct to the work without the losses inherent in converting it back nto heat, the natural field for fuel. As petroleum is cheap and coal abun- ant in the West, whatever process in steel fabrication needs had best be rown from them. Incidentally it is in this branch of the steel industry hat there is most hope of finding solution of post-war employment problems.

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In considering the probable future of the western steel works, many factors must be considered. These include cost of raw materials, and of operations, size, situation and variety of markets, competition, taxes, labor supply and other less important items. In discussing these it is necessary to discriminate among the nonintegrated plants, such as those along the Pacific coast; the fully integrated plants, such as those at Pueblo and Geneva; and the less-complete plant at Fontana.

The coast steel plants have now had a history of a half century or more. They have weathered severe storms and demonstrated their usefulness continuing to grow and to add to the line of products that they manufactu as markets appeared. They are favored by cheap fuel from the oil fields, by an abundant and as yet cheap supply of scrap, and by nearness to the market. They have had an advantage of $5 to $20 per ton over competitors who had to absorb at least that amount in freight charges to reach into their market. They now have the assurance of a local supply of pig iron, which may be bought to supplement their supply of scrap if the latter becomes scarce or expensive. Although they must work with cold metal, the extra cost of melting is becoming decreasingly important; and where cheap fuel is available, as it is in California, the significant extra cost becomes one largely of lower capacity of the furnace.

The plants are, it is true, small, and can no more stand the impact large-scale units such as a continuous sheet and strip mill than could th in the East and Middle West when continuous mills came into operation. T economy of a continuous mill, however, only comes into play when the opera tion is really or nearly continuous. This requires large orders for individual products - a situation that does not hold in the far West. There i no big industry there, such as automobile manufacture in the East, which can absorb enough of one product to keep such a mill fully occupied. Orde involve a few hundred tons at a time of each size, quality, or finish, an the smaller mills find no difficulty in competing in such a market. A co promise operation is coming to be employed in the Middle West, where some of the mills face the same problem. Here the big strip mill works on a limited number of standard-gage strips or "bands" which are carried throug to an approximate thickness and stored in coils. When an order is to be filled the needed steel is cut off from the coil and finished on smaller rolls. This competition may cut into the market or prospective market of the coast mills when Geneva reaches capacity, but in general they have little to fear from intensified competition from the East.

The small mills have an advantage in capital charges; although they cannot manufacture a full line of rolled products, they are adapted to su a considerable portion without the carrying charges incidental to the hea and expensive machinery in the newer and larger plants. In general, the capital investment per ton on the small mills is relatively low, and in t present instance there is the further advantage that the plants have reac their present size largely through plowing back profits. That is the gen rule in the steel industry, and there are large plants in which the prese capital is as much as eight times the initial investment and yet substantially no new money has gone into the plant; the plant has grown from wit

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nd paid for itself. In this detail the new wartime-built steel mills hroughout the United States are at a distinct disadvantage in competition nless the Government, which ordered them built and supplied the money, s willing to charge off most of the expenditure to war expense. As has een remarked, this would be essentially as fair as the practice of charging ff battleships, which are not expected to be amortized.

MARKET OUTLOOK FOR WESTERN STEEL

Geographic Factors

Nearness to markets is one of the factors that promotes the success of steel plant, and some of the most successful have been located where they re primarily because of such nearness. The chief advantage of the whole rthern Indiana-Illinois steel industry is that the mills are in the enter of a large local market and the numerous railways centered there fford exceptional facilities for reaching markets in a wide area around. o make steel in the Chicago district, all the raw materials must be brought n except scrap, which is abundant; wherever a market for steel exists there s a corresponding production of scrap from its fabrication. This density f and variety in local markets may far outweigh other considerations. Contrast, for example, Duluth and Chicago as steel-making centers. At Duluth he iron ore is at hand and coal is brought up the Lakes as return freight t an extremely low rate. Coking coal costs little if any more at Duluth han at Chicago, and furnaces were built at Duluth before they were at Gary. he larger market, though, is in and around Chicago or in districts more asily reached from there, so the Minnesota plant now produces 610,400 ons as against the 10,922,000 of the Indiana furnaces. The pull of market nd of scrap which is closely tied to the market itself has determined this esult. Any realistic consideration of the probable success or failure of steel plant in any particular locality must consider such factors.

In pre-war days the Western States afforded a market for about 3,500,000 ons per year of steel, figured back to ingot. This included steel locally anufactured or shipped in as finished or semifinished material but not that n manufactured articles, such as automobiles, steel furniture, machinery, r any of the thousand and one articles into which steel is put before it eaches the final customer. It consisted of steel made locally for casting nd rolled products or shipped in. Furthermore, only steel in the major lassifications, such as rails, bars, plates, sheets, tubes, wire, tin plate, ails, bolts, and similar articles, is here included. For each of these, r for groups that can be made in one plant, the market was sufficient to permit manufacture in plants of economic size.

At that time the ingot capacity of the western works totaled a trifle ver 2,000,000 tons, leaving a considerable gap to be supplied from outside. his gap in the local market was filled by shipments from eastern works, ainly those that had easy access to the sea, such as at Baltimore and irmingham. Others participated in the trade and some as far west as ittsburgh sold special products, or standard shapes in times of special emand, although generally the added cost of railway haul to the point of

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transshipment to steamer prevented them from doing so. Virtually all move ment of eastern steel to the Pacific ports was by water. Since the war began, "all-rail" hauls have had to be substituted, and steel has flowed to the West in quantity from inland producing districts as well as from seaboard and near-seaboard plants. This movement is not likely to be important after the war.

Steel production in the West has grown up in two regions - at the eas front of the Rocky Mountains and in the cities along the Pacific coast. T corresponded to two centers of demand of approximately equal importance. eastern plant, at Pueblo, has served the whole Rocky Mountain front and t some extent has stretched West clear to the Pacific where, for example, i has supplied rod f a wire mill in the San Francisco area. From the firs the Pueblo works has made pig iron as well as steel, and in manufacture le dependence has been placed on scrap, which indeed was not available in quantity when production was begun. Based largely on the Pueblo works, co siderable local manufacturing has grown up in Colorado in response to spe demand, as for mining machinery, in which the special knowledge of the loc industries to be supplied has been important. The works of such companies as Colorado Iron Works, the Stearns Roger Co., Vulcan Iron Works, Mine & Smelter Supply Co., Wilfley Manufacturing Co., and others that might be named illustrate how a steel works in time attracts or creates local fabri cating plants and so generates its own market and scrap supply. The Pueb plant, at the edge of the Great Plains as well as of the mountains, early found a market for wire and wire products in the farming and ranching cou this has grown steadily with closer settlement of the country, while the s of distribution has expanded with expansion of the railway network. A lar proportion of the steel made at Pueblo has been sold in States south and e of Colorado. As the plant has expanded and its product has been increasi diversified, its market has grown until in 1941 it is reported to have mad sales in 34 States and 34 foreign countries.

On the Pacific coast steel production began at much the same time in the Bay region at San Francisco, in southern California near Los Angeles, and in the Northwest at Seattle and Portland. Small plants were at first put up to roll or reroll steel made from scrap. Later the needs of the gold-dredging industry led to melting scrap to make steel castings, and other lines of manufacture were taken up as opportunity permitted. At first the plants were all small, served local markets, and were locally owned. Later the Columbia Steel Co., financed in San Francisco, Calif., expanded its plant at Pittsburg in that State, acquired and improved the mill at Torrance near Los Angeles, and in 1924 built and put into producti a blast furnace at Provo, Utah, to supplement the scrap supply with pig iron. This company was absorbed by the U. S. Steel Corporation, and about the same time Bethlehem Steel, already owner of the old Union Iron Works at San Francisco, acquired others in the Los Angeles and Seattle district The Judson Steel Corporation maintained its independence at Oakland, a small early plant at Portland went out of business, and a small electric furnace plant came into operation near Seattle. In 1938 ingot capacity was divided about as follows:

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	Net tons
Columbia	494,500
Bethlehem	425,600
Judson	85,700
Northwest rolling mill	16,800
	1,022,600

addition the Pacific States Steel and The National Supply Co. now manu-cture some 132,300 tons for rolling and casting.

The total capacity of these plants was then a little less than that of e Pueblo plant of Colorado Fuel & Iron Co. Since the various plants sell some extent in each other's territory and there is some cross hauling, d also since shipments from outside the area are somewhat larger than the unts locally produced, the market requirements divide up slightly dif-rently from the way local capacity to produce does. Various market sur-ys differ slightly in results, but a fair generalization would seem to that the two Northwestern States normally afford a market of 15 to 18 rcent of the total for the coast and that of the remainder a little more an half is sold in or through Los Angeles and a little less than half in e bay region of San Francisco. Steel to be made in Utah will crowd into ese markets mainly since only a small part of the output of the Geneva nt can be expected to find a market to the east and north. The situ-ion of the Geneva plant is such that it can deliver with approximately ual facility and cost to any of the three centers of consumption on the ast.

Influence of Freight Rates

Assuming that the cost of making steel at western plants will not in self be enough greater than at competing plants to throw them out of mpetition (and this assumption seems to be sound), the division of the rket will in future be determined by relative freight rates and merchan-sing cost and ability. The fact that American steel works generally ab-rb part or all of the transportation charge to widen their market indicates at freight is not the controlling factor in most of the sales. The mark-from cost to sales price in the case of steel, as for most goods, is much re than the freight to the delivery point. It is true that prices over e whole country have been fixed on the so-called "Pittsburgh plus" basis - minally the Pittsburgh or other base point price plus the freight to livery point - but the actual freight charged has sometimes been more and metimes less than the nominal rate. For example, where deliveries have en made by river barge the charge has nonetheless been based on railway liveries. Moreover, sales in distant territories have often, if not nally, been made at prices less than the base rate plus freight to in-rease the volume of sales and so keep the mill running at capacity. It charged, too, that the price fixed for deliveries at or near the point production is loaded to permit absorption of part, at least, of the st of reaching distant markets. There is reason to think that there is ch in this contention. In rebuttal, the steel companies cite the fact at the largest single element in cost at a big modern works is the ratio

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of the rate of production to capacity. By so fixing prices as to secure the highest rate of production feasible, the lowest costs are made possib which, in turn, permits the lowest average price to all buyers.

It is to be remembered that, by reason of the size of the units concerned and various subsidiary factors, the prices of steel products are not entirely fluid, and changes can only be made slowly and to a limited extent. The effect of a cut in the selling price of one line of goods i a particular locality at any time is too far-reaching to permit the step to be taken lightly. Its influence spreads like the ripples in a pool when a small pebble is thrown in. For these reasons, large changes in steel prices usually come slowly, and competition in sales depends in large measure on other factors (such as service, aggressiveness, financia connections, and favor), as well as on actual cost. It is to be expected that in the post-war period of adjustment of over supply to actual marke reductions will be made but nothing revolutionary is to be anticipated.

The Western States anticipate that cheaper steel will be available f local use; this will undoubtedly be true as compared with wartime prices based upon necessity and scarcity. At present steel is being delivered t western consumers at prices based upon all-rail haul from Pittsburgh, Chi and other interior points. When intercoastal shipments are resumed the p should go down to base cost plus steamer rate, the latter being slightly over $10 a ton. It can go lower and the principal eastern works remain i the field, since both of the larger companies that supply the western mar ket operate their own shipping lines and actual costs are naturally less than open rates. No figures are available as to what this actual cost is but it may be as little as $5 per ton. Since ships carry many products s back as well as forward moving freight must be considered, the shipping industry is one that faces all the difficulties of mixed costs. The actu cost of carrying steel to the Pacific coast no doubt varies with each voy and, to a smaller extent, with each shipment of material. It is probably as nearly accurate as can be named in advance to say that the coast plant will have a general average advantage of $5 per ton in cost of delivery t market. Presumably some of this will have to be passed on to the custom to obtain a satisfactory share of the market heretofore supplied from eastern works.

This differential applies only to the plants on the coast itself, wh as it happens, the largest market lies. The coast plants will be handica by their smaller size if the large plants can run at a fair rate of cap The Geneva and the Pueblo works are large enough to compete evenly, but b cause of Geneva's interior position it probably will need the whole of it freight differential in order to make deliveries on the coast where most the market is the Pueblo will continue to be handicapped in reaching the coast market. At present the freight rate, even on Government goods for Government use, from Utah to the coast is $8.50 per ton, intermediate be- tween the intercoastal water rate and probable real cost of intercoastal shipments. Open freight rates from Utah to the sea are higher, as there has been very little freight movement to create a demand for lower rates.

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t would appear safe to assume that after the war the whole rate situation ill be studied and such revisions made as will permit even competition of e various plants operating in the Western States, that being the general ilosophy of the freight-rate structure in the United States. In this neral readjustment it is not likely that Geneva will be placed on abso- ute equality with the coast plants, but it will have in reserve the eco- mies incident to large production in an integrated plant. In the sale of g iron the Geneva and Provo furnaces will have a large advantage if and en the price of scrap rises on the Pacidic coast. The normal difference price between pig and scrap is of the order of $2 to $2.50. The freight te on pig from Utah to the coast is now $4.95 per gross ton so that at very slight increase in scrap price the two will become closely com- etitive and then the coastal plants may be expected to use more pig in king steel.

The Fontana plant is in a special situation. By reason of its location is a coastal plant so far as deliveries to the market are concerned, and competition with steel from the East it should enjoy nearly the full dif- rential of freight. Its cost of manufacture will be determined, as in all ch plants, by the rate of production the managers are able to maintain. t will be favored by a low unit cost of its iron, although there are dif- iculties to be overcome due to the presence of undue amounts of sulfur in rt of the ore bodies. It is handicapped by its distance from coal and he moderate quality of the coke that may be made from it. It should dominate he market in the Los Angeles district, which is the largest on the Pacific oast, and in reaching other Pacific markets should be at least on a par ith eastern competitors. All this, however, is contingent on success in efinancing the plant and on its financial support thereafter, as well as n the ability of its sales staff.

The Pueblo plant is also in a special situation. It has not been able n the past to make any heavy inroads on Pacific coast or foreign markets, lthough sales are made in each. It has cultivated - and probably must ntinue to do so - the local market in Colorado and adjacent States from he crest of the Rockies as far east and south as possible. In this the mpany has heretofore done well, though not spectacularly so. A new lement is entering the situation in the building of a steel works at ouston by the Sheffield Steel Corporation, which already operates a small lant at Kansas City similar to the Pacific coast steel works. It is under- tood that Sheffield Steel is a subsidiary of the American Rolling Mill Co., concern with well-established markets, especially for sheets. The Houston lant has several advantages, namely, low fuel cost, reasonable nearness to oal fields from which good coke can be made, a fair position as to scrap nd local markets, and a seaboard location. Its iron-ore situation is not ntirely satisfactory, and the supply from Texas is now being supplemented y purchases from Mexico. If later the company finds and buys a good de- osit near the sea, especially if in one of the Caribbean countries, the lant will be in a strong competitive position. From it the Colorado Fuel Iron Co., especially, can anticipate stiff competition in much of the erritory heretofore served from Pueblo. The entrance of either on any large scale into the field west of the mountains seems improbable.

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Total Market for Western Steel

In the light of the general situation outlined above it is now possib to review the probable future market for western steel plants. In the pre war days steel to a total amount of slightly over 2,000,000 tons of ingot was produced in these States. At the same time, rolled products were brou in so that the total steel marketed in the West was equivalent to approxi- mately 3,500,000 tons of ingots. Since 1938 there has been added to local capacity to produce some 2,600,000 tons calculated as ingots. There is nc therefore 4,600,000 tons capacity to produce as against a pre-war consumpt of 3,500,000 tons. If, therefore, the local works sell their entire outpu in the local market there will be no room for competition from eastern fur naces. However, it will probably prove more economical to bring in from the East certain steel products, especially the heavier shapes. It is als possible for the western plants to take over some of the offshore market. Otherwise they will have to be content with a 75-percent ratio of operatic or less. The eastern plants will lose an important amount of market, but there will need to be similar adjustments as between eastern and middle western plants where also there has been material building of plant. It can hardly be expected that the older plants should hold all their pre-war markets in the West and absorb their losses elsewhere. It is also to be remembered that the total Western States consumption is only about 3 per- cent of the capacity to produce in the country as a whole and that the difference in output of the industry at the 96.8 percent of capacity in 1942 and that of 81 percent in 1940 amounted to 7,267,054 tons, against which the figures for the West do not look large. It should not be for- gotten that when the steel industry is operating at 75 percent capacity it has been heretofore customary for the steel companies to consider conditio highly satisfactory.

Export Market. - Claims frequently have been made that any deficiency in local market can easily be offset by sales abroad and, again assuming that the cost of production in the West is reasonably near that of com- peting furnaces now selling in the Pacific market, there may be something in this claim, but it would only be in the very long run that western fur- naces can expect to find any large market abroad. Nevertheless, a locati on the seacoast opens many roads to market, provided the flow of trade in general brings ships to the home ports. Mere advantage in distance is not enough, as witness the failure of Prince Rupert in Canada to secure any co siderable portion of the trans-Pacific trade despite offering the shortes distance to the Orient. There are many considerations that enter into international trade, and it is difficult to fortell accurately what part of a market a newcomer will be able to capture. At present, Pacific coas ports have no advantage in trans-Pacific freight rates on steel despite th longer haul from the East and the necessity for payment of canal tolls by ships loading there. Back freight and volume of trade count for more than mileage in this case. There is also the fact that the eastern and foreign steel makers have established markets in the trans-Pacific countries for some or all of their products and have already on the ground experienced marketing organizations that have taken years to build up. A newcomer wil need much more than an advantage in cost, if indeed in this case he has th to capture any considerable share of the market.

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In pre-war days the total steel exports of the United States to Pacific rts of South and Central America, Mexico, Japan, China, and other countries oing that ocean were roundly 1,000,000 tons a year. About one quarter illion tons more went to Alaska, Hawaii, and the Philipines, making a ugh total of 1,250,000 tons of American steel sold in the countries facing e Pacific. However, of this amount 484,000 tons in rolled products and g iron went to Japan, and it is improbable that in the post-war years at country will be able to buy any such quantity from us. It is also ue that since Manchuria is to be restored to China the latter will in- rit a considerable share of what has heretofore been Japanese capacity produce; when Korea is made independent, this will cut into the Japanese gures further so that pre-war markets are due for a considerable shake- , although this may merely mean a trade in customers, not any significant crease in consumption. Immediately after the war and throughout the period reconstruction China doubtless will afford a considerable market for erican steel if sales can be financed, but in the long run the Chinese obably will manufacture their own steel and will also wish to export. at has already happened in India and Australia, where there are large dern plants. Several of the other Pacific countries are ambitious to ild and operate at least small steel plants. Not all of them are in a dition to do so economically, but some may be. In the Philippines, as e example, it will be entirely possible to make about half the steel now ported without getting into the field of diminishing returns because of er-investment in heavy equipment or of finishing plants which the local rket is not large enough to support.

It is also to be remembered that the British and European steel plants ill be hungry for markets in the post-war world. In the past they have mpeted strongly in the trans-Pacific markets and may be expected to do o again. The immense buying power of Europe for far eastern products ives it a heavy leverage when it comes to selling there. Germany has been he chief market for soy beans from Manchuria, and that, in reverse, has pened the way for sales of German steel and German machinery there and in apan. Unless we develop additional buying power out there we hardly can xpect any large increase in sales, but that is a general problem faced by ll international traders. It is recalled here to emphasize the fact that n estimating the future growth of steel manufacture in the West it is neces- ary to consider many elements other than capacity to produce goods at mpetitive costs.

In one field the western furnaces have an advantage which they are not ikely to lose, although it is a small one. Hawaii buys a trifle over 0,000 tons of steel a year from the mainland, and on structural steel, lates, sheets, and tin plate there is a differential of $4.70 per ton in avor of the Pacific ports for ocean shipments. Since there is a large rade in island products delivered to the West coast, this differential would eem likely to be maintained and probably similar rates can be had for other teel products. The Alaska trade is also one in which the western producer as an advantage. The consumption there is, however, small - about 50,000 ons - and can only be expected to grow slowly with the growth of the opulation and industry of the Territory.

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Light Steel Products. - The room for expansion of output in the West lies dominantly in light rather than heavy steel products. The market in large shapes and in rails is very uncertain at best. Taking the countr as a whole, it is overbuilt as to rails and probably so as to heavy beams. The tendency is toward use of lighter products, even where large girders must be employed. It will be venturesome to equip for such heavy products although it may prove economical at Geneva or Fontana, since the major part of the investment has already been made and the part-time use of the additional equipment by increasing volume of output may be profitable. In general, although the mills must look for their market in the fields of lighter structurals, sheets, tubular goods, bars, rods, wire and similar products, there are well-recognized deficiencies in production of tubular goods and sheets and especially of tin plate. It would seem not impossibl for local plants to push into the markets for these products. Tubular goo totaling 200,000 to 250,000 tons were being brought into the Western State in pre-war years, and tin-and terne-plate inbound shipments were of the order of 200,000 tons. To this may be added perhaps half as much more for direct shipment to Hawaii and other Territories which might reasonably be supplied from western plants. Various market surveys have been made, and although the figures arrived at vary somewhat it is clear that there is a market large enough to support at least one tin-plate mill and one tubular mill of economic size if the necessary conditions of manufacture and marke connections are met. These will not be easy.

Tin Plate. - The major consumption of tin plate is in the manufacture of cans for food products, oils, and other packaging. In the canning indu try the West holds a large place, and it has been estimated that approxim one-third of the cans made in the country are sold in the Western States, Hawaii, and Alaska. The canning of fruits, vegetables, and fish is a big and growing industry in this region, and the future for sales of tin plate in it is undoubtedly bright. Most of the sales are, however, to the can-neries, which buy cans, not tin plate. The cans in turn are made almost entirely by the Continental and the American Can Cos., which have well-equipped factories in all parts of the country and well-established con-nections both as to tin-plate supply and can sales. Competition with eith would be serious and expensive; presumably, concessions in price would be necessary to divert trade from present sources of supply of plate, which are now mainly in the Pittsburgh-Indiana region. Just how far a local mi could afford to go in cutting prices to get into this market cannot be sa estimated by anyone but the manufacturer himself.

One phase of the matter which is probably not adequately appreciated that the making of tin plate suitable for use in food containers is much more difficult than is generally thought. The steel for such use must be a particular quality and receive special treatment in manufacture.11/ The quantity of tin used to cover the steel is small and the coating very thi

11/ Hartwell, R. R., Corrosion Resistance of Tin Plate. Influence of St Base Composition on Service Life of Tin Plate Containers: Paper be Am. Soc. Metals, Cleveland, October 1940.

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ny minor protuberance of steel will therefore project through the tin coating and permit direct contact between the food and the steel, which will ultimately result in spoilage. There is no such thing as an absolutely continuous coating of tin, so the quality of the steel is highly important, especially if the can is to be used as container for the dark fruits and certain vegetables, such as are put up largely in the Pacific coast States. These contain juices that are especially active in attacking steel.

Not only must the surface of the steel be made as smooth as possible, which is usually accomplished by finishing on cold rolls, but the composition needs to be such as will enable it to stand the severe bending and rebending incident to can manufacture without opening up and exposing the steel underneath. It happens that steel killed by using ferrosilicon, or bonderized or otherwise surface-treated with phosphorus, ravels at the surface when given this hard treatment. It is an odd circumstance, too, that the presence of a mere fraction of a percent of copper is also bad, despite the fact that a similar amount is beneficial for many uses of steel and particularly in sheets, where it ordinarily operates to delay or defeat corrosion. The copper tends to segregate along intercrystalline boundaries and ordinarily seals them against ingress of corrosive agents. In making cans, however, the presence of a different material along such boundaries localizes the stresses and causes the material to open up enough to permit contact between the fruit juice and steel. Canners recognize two grades of tin plate, one suitable for dry packaging, putting up oils, milk, most vegetables, and many fruits, and another that alone can be used for all purposes. It has already been suggested that the fruits put up in the Northwestern States and certain vegetables require this higher-grade tin plate.

Most western iron ores contain minor amounts of the sulfides, including the various copper ores. It will require considerable care in selection and treatment of the raw materials to make steel suitable for rolling into plate for tinning since so considerable a portion will find its market in the making of cans. For other sheet uses these peculiarities are not so important, and market requirements for galvanized products and ordinary black sheet can be easily met.

Automotive Parts. - In passing it may be recalled that while the most striking change in demand for steel in recent years has been the increased call for sheets, the largest factor in this has been the building up of the automobile industry. The peculiarities of automobile manufacture - mass production and the emphasis of standarized quantity production in order to meet the price requirements of the market - offer little encouragement for expecting automotive plants to be established in the Western States. Although these States are said to absorb 15 percent of the national output of automobiles, that in itself is not a sound argument for expecting a local plant to succeed. One needs only to travel the roads in the West to see that the equipment in use there includes many makes and many styles. No one plant could make all of these and still be on a competitive basis with existing manufacturers each of whose plants would have the advantage of volume and resulting lower costs. To make automobiles cheaply, large plants

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are necessary and production must be on a volume basis. The manufacturers in the Detroit region, by meeting these requirements, can sell around the world in competition with local producers except where hindered by high tariffs, quota restrictions, or other artificial handicaps. They would have none of these to face in competing with a western producer and only some single type of special car would have any present chance of success.

There is, however, one way the western plants may enter the automoti field - by specializing in parts manufacture. As is well-known, the auto mobile companies depend on assembly lines and have established plants to put parts together in various places here and abroad, since finished cars are bulky and expensive to ship while parts may be packed and shipped at much less cost. It is also possible to manufacture parts at many places where it would be impractical to build whole cars or trucks, and a factor to make a particular part need not be enormous. This system of manufactu has been used to good advantage in the subcontract system of making war goods. It would seem feasible to broaden it in peacetime. Indeed, for some years the A. O. Smith Co. at Milwaukee specialized so successfully in building automobile frames that it made them for all the companies but Ford, and the last company itself has gone perhaps as far as any in estab lishing and supporting parts plants in various parts of the world. To Ja for example, Ford steamers brought only parts for Ford cars. These were assembled there with the addition of other locally made parts, and the steamer carried from Japan a supply of locally made parts for use in Ford numerous plants in other countries. An extension of this system of manu-facture would open the way for western plants to find a market, even when local conditions do not favor entering the field with a wholly finished product.

Finished Products. - The field is, however, by no means closed to co plete manufacture and sale of finished products both at home and abroad. With cheap fuel in California and cheap power in Oregon and Washington, t manufacture of consumers' goods should grow rapidly if specialties are developed and an efficient marketing organization is built. Pelton water wheels, designed to meet the special situation in Califonia of numerous small, but high-pressure water powers, have long been sold around the wor A few years ago a Nichols-Herreshoff roasting furnace made in San Francis was sold to one of the U. S. Steel Corporation subsidiaries for use in Pi burgh, Pa. Wilfley tables have been shipped from Denver all over the wor and the Colorado Iron Works and other Denver companies sell in many lands despite distance and freight rates. Over 40 years ago one of the old iro manufacturers at San Francisco, losing much of the business on which it h grown up because of changes in the mining industry, designed and built a farm tractor that found its largest market in Argentina. Since the shop cost was $800 and the delivered price $2,400 the business was profitable despite all handicaps. Many other instances could be cited, but enough has been said perhaps to make clear that the order of thinking rather tha some minor diference in cost of manufacture determines success or failure

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ADJUSTMENTS REQUIRED FOR POST-WAR OPERATION

Adjustment of the western steel industry to meet peace rather than war nditions will clearly require a number of changes. It has already been ntioned that the capital structure of the new war plants will need ad- stment. This is all the more clear since it will require further ex- nditure to equip them to change over from making the present large nnage of ship plates to that of manufacturing tubular goods and tin plate - e two major gaps in the present line of local production. Considerable ms will be needed for this, with smaller additional or alternative amounts rails or other new products are to be manufactured.

A radical remaking of the freight-rate structure of the region will so be required and may be expected. The war has brought the Pacific rail- ys increases of 4 to 12 times their pre-war tonnage of steel-classification eight. In 1940 the seven western railways moved 1,642,965 net tons of iron d steel products and received $9,715,608, an average of $5.92 per ton, as eir share. By 1942 the tonnage had grown to 8,109,922, and the distance ved had lengthened by two-thirds, with corresponding increase in revenue. itting duplications, it is estimated that the transcontinental lines have r some time been moving about 5,000,000 tons of steel a year into the West. is to be anticipated that, with the end of the war and resumption of tercoastal marine traffic, the bulk of this tonnage will be lost to the ilways. Some of it will disappear entirely as shipbuilding on the coast ntracts. In 1936-37, about 1,200,000 tons of iron and steel passed through e Panama Canal so that much of the tonnage the railways now have is new, effect of the war. Faced with the prospect of the loss of substantially l of this rich revenue-producing freight, the roads may be expected to be en-minded as to readjustments necessary to build up local traffic instead. few changes have already been made. The pre-war rate on finished steel om Utah to the coast was $12 per ton. The Western Pacific has now named rate of $8 to San Francisco, and the Union Pacific one of $9.50 to Los geles and Portland, with slightly more to Seattle. Some of the new rates re established for Government-owned goods to Government plants, but there s little question but that they will become public rates in due time. A eginning has thus been made in rate adjustment, and it does not seem un- easonable to expect local rates of $5 to $6 per ton in future. Some ex- sting rates already approximate this as shown below:

	Per long ton
Pig iron, Provo to San Francisco Bay points	$4.95
Billets, Provo to San Francisco Bay points	5.78
Cast-iron pipe, Provo to San Francisco points	7.39
Sheet bars, Provo to Los Angeles or San Francisco	6.05

The importance of freight rates in cost of raw materials and finished ods delivered has already been emphasized. For the Geneva plant the latter s an outstanding factor. For Fontana it is the freight on raw materials, w amounting to nearly $10 per ton of pig iron, which is critical, although t is offset to a large extent by location of the plant in the midst of the

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largest consuming and scrap-producing center on the coast. To the coast plants the cost of delivered pig iron is significant; for their survival, this cost must be kept low enough to offset possible increases in the cost of scrap.

Post-war prices of steel enter significantly into the problem, as they do in all other industries. It has already been indicated that in cost of iron and steel it is the capacity and rate of production that are most influential. The two new plants place the Far West on a par with other parts of the country, and there seems no sure reason why there should be, on the average, any material difference in the rate of operation in the West and the East in the post-war period. The plants are within reasonably competitive range as regards fundamental costs. In general experience western workmen are as efficient or possibly more so than those in the East and Middle West. The climate is favorable to industry. The tax situation is not bad. Although California has the reputation of being a high-tax State, Utah rates are low and Colorado medium. At present iron ores in the West are not faced by the high taxes and royalties that obtain in the Lake Superior region; but too much should not be counted on as to this, since taxes have the habit of coming around to what the traffic will bear, and the States will be called upon for heavy expenditures.

Opinions differ as to the general state of prices in the post-war period with perhaps the major opinion being that inflation will have raised the level. At present costs of manufacture everywhere are high, but a considerable reduction in unit costs may easily be achieved without affecting wage rates by cutting off overtime as pressure for output decreases. It is not to be expected that the present high rate of operation in the steel industry will continue, but it can fall a considerable distance and still be at what in pre-war years was considered satisfactory. There will be periods of slack demand and probably shutdowns will be necessary in the West, as in the East, but more and more steel will be made in the Western States, and if local manufacture of products made from steel is pushed vigorously the employment situation may be materially helped and a sound industrial structure created and maintained.

SUMMARY

The eleven Western States have been growing more rapidly than the remainder of the country. During the last 40 years the population of the West has increased nearly 240 percent, whereas that of the other 37 States rose only 64 percent. Accompanying this rapid gain in population has been an increase in steel consumption and production in the Western States. Because the war has added considerably to the local production capacity a question arises as to the outlook for continued use of the expanded capacity in the post-war years.

Before the war the West had plants capable of producing 2,019,000 net tons of ingot steel per year and afforded a market for steel products equivalent to approximately 3,500,000 tons of ingots, a substantial part of which was supplied by plants in the Central and Eastern States. War expansion h

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ised production capacity to 4,655,000 tons, or considerably above pre-war rkets. Post-war operation of the new plants will depend upon the success-l attainment of several objectives, including:

1. Recapitalization to eliminate that part of the investment chargeable to war expense and provision of adequate financial backing to meet required post-war adjustments.

2. An agressive marketing program to develop outlets for more steel products and to capture markets previously supplied by eastern plants. Light rather than heavy steel products offer the best opportunity for expansion; the potential market for steel in tin plate and tubular goods manufacture is substantial.

3. Radical adjustments in freight rate structure.

4. Technical progress to overcome:

   a. Limiting effects of certain impurities in western iron ores.

   b. Deficiencies in western coking coals and lack of markets for coke byproducts.

   c. Possible future deficiency in local scrap supply.

Careful analysis of the various factors involved in attaining the ove objectives indicates that there are serious problems to overcome but at they do not present insurmountable barriers to post-war operation of e new western steel plants at a reasonably satisfactory rate.

CONCLUSIONS

Subject therefore to the reservation of the necessity for recapitalation of the new plants and for providing them with adequate financial oking, a favorable answer may be given to the questions raised on preding pages, namely:

1. The raw materials needed are available in sufficient quantity, and though there are defects in quality to be overcome they are not insurountable. Assembly costs that are reasonably competitive with those elsere may be attained.

2. Markets are open which are adequate to support production in plants economic size, subject to the usual vicissitudes of the steel business t permitting expectation of growth.

3. With capable management, it should be possible to operate with nversion costs that will be competitive.

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